

Patent claims:

1 1. A method for determining the distance between two
2 transmitting and receiving stations (1, 2), characterized
3 in that

4 in each transmitting and receiving station (1, 2) a
5 transmission signal (S1, S2) is generated and is
6 transmitted as a series of microwave pulses having a
7 predefined pulse repetition frequency (fp1, fp2) to the
8 respective other transmitting and receiving station (2, 1)
9 and is received thereby in the form of a received signal
10 (E2, E1), said pulse repetition frequencies (fp1, fp2) of
11 the transmission signals (S1, S2) varying according to a
12 predefined differential frequency value (fd),

13 in each transmitting and receiving station (1, 2) the
14 coincidence of pulses of the transmission signal (S1, S2)
15 sent by the respective transmitting and receiving station
16 (1, 2) and the received signal (E1, E2) is detected as a
17 coincidence event,

18 for each transmitting and receiving station (1, 2) two
19 numbers of pulses (m(i), n(i), p(j), q(j)) allocated to the
20 respective transmitting and receiving station (1, 2) are
21 determined, which as a transmission pulse number (m(i),
22 q(j)) and as a received pulse number (n(i), p(j)) represent
23 the number of the pulses transmitted and received by the
24 respective transmitting and receiving station (1, 2) at the
25 point in time of a coincidence event,

26 the distance between the transmitting and receiving
27 stations (1, 2) is calculated from the numbers of pulses

28 (m(i), n(i), p(j), q(j)).

1 2. A method according to claim 1 , characterized in that
2 for each transmitting and receiving station (1, 2) the time
3 interval (a+b, b-a) between the first pulse transmitted
4 from the respective transmitting and receiving station (1,
5 2) and the first pulse received by the same transmitting
6 and receiving station (1, 2) is determined from the numbers
7 of pulses (m(i), n(i), p(j), q(j)) determined for the
8 respective transmitting and receiving station (1, 2) and in
9 that the distance between the transmitting and receiving
10 stations (1, 2) is calculated by summation of the
11 determined time intervals (a+b, b-a).

1 3. A method according to claim 1 or 2, characterized in
2 that a range measured value (x) is calculated as a measure
3 of the distance between the transmitting and receiving
4 stations (1, 2) as per the equation

5
$$x = ((m(i) - p(j)) \cdot g - ((n(i) - q(j)) \cdot h,$$

6 wherein

7 g and h represent the periods (Tp1, Tp2), scaled to a
8 reference time (T0), of the transmission signal (S1, S2)
9 transmitted from the one or the other transmitting and
10 receiving station (1, 2),

11 i and j represent counting variables for the number of
12 coincidence events detected at a certain point in time in
13 the one or the other transmitting and receiving station (1,
14 2),

15 $m(i)$ and $n(i)$ represent the transmission pulse number and
16 received pulse number allocated to the one transmitting and
17 receiving station (1) at the point in time of the i^{th}
18 coincidence event and

19 $q(j)$ and $p(j)$ represent the transmission pulse number and
20 received pulse number allocated to the other transmitting
21 and receiving station (2) at the point in time of the j^{th}
22 coincidence event.

1 4. A method according to one of the preceding claims,
2 characterized in that the numbers of pulses ($p(j)$, $q(j)$)
3 determined for the one transmitting and receiving station
4 (2) are transmitted to the other transmitting and receiving
5 station (1) by modulation of the transmission signal (S2)
6 generated in the one transmitting and receiving station (2)
7 and in that the distance between the transmitting and
8 receiving stations (1, 2) is calculated in this
9 transmitting and receiving station (1).

1 5. A method according to claim 4, characterized in that the
2 transmission signal (S2) is modulated by phase modulation.

1 6. A method according to one of the preceding claims,
2 characterized in that the numbers of pulses ($m(i)$, $n(i)$,
3 $q(j)$, $p(j)$) are determined by counting the pulses
4 transmitted and received by the respective transmitting and
5 receiving station (1, 2).

1 7. A method according to one of claims 1 to 3,
2 characterized in each transmitting and receiving station
3 (1, 2) the pulses transmitted are counted to determine the
4 transmission pulse counter states (m , n).

1 8. A method according to claim 7, characterized in that the
2 transmission pulse number ($q(j)$) and received pulse number
3 ($p(j)$) are determined for the one transmitting and
4 receiving station (2),

5 by choosing a pulse (mz), which corresponds to a certain
6 transmission pulse counter state (m), from the transmission
7 signal ($S1$) generated in the other transmitting and
8 receiving station (1), and by shifting this pulse (mz) in
9 time or suppressing it,

10 by testing, whether in the one transmitting and receiving
11 station (2) the next coincidence event appears at an
12 expected point in time, and

13 by allocating as a transmission pulse number ($q(3)$) the
14 transmission pulse counter state (q) to the one
15 transmitting and receiving station (2) determined at the
16 expected point in time in it and as a received pulse number
17 ($p(3)$) the transmission pulse counter state (m) of the
18 chosen pulse (mZ), if at the expected point in time there
19 is no coincidence event.

1 9. A method according to claim 8, characterized in that the
2 method steps in the case of a coincidence event appearing
3 at the point in time to be expected are repeated with new
4 chosen pulses until a coincidence event fails to appear at
5 an expected point in time.

1 10. A method according to claim 8 or 9, characterized in
2 that the transmission pulse numbers ($n(i)$, $p(j)$) are
3 similarly determined for both transmitting and receiving

4 stations (1, 2).

1 11. A method according to one of the preceding claims,
2 characterized in that the differential frequency value (fd)
3 is substantially smaller than the pulse repetition
4 frequencies (fp1, fp2) of the transmission signals (S1,
5 S2).

1 12. A method according to one of the preceding claims,
2 characterized in that between the transmitting and
3 receiving stations (1, 2) data are transferred by phase
4 modulation of the transmission signals (S1, S2).

1 13. A method according to one of the preceding claims,
2 characterized in that in the transmitting and receiving
3 stations (1, 2) the transmission signal (S1, S2) generated
4 in the respective transmitting and receiving station (1, 2)
5 is converted with the received signal (E1, E2) received by
6 this station by mixing into an intermediate frequency
7 signal (Z1, Z2), and by converting said intermediate
8 frequency signal (Z1, Z2) by filtering and envelope
9 demodulation into a pulsed evaluation signal (D1, D2) and
10 by determining the position in time of the pulses of the
11 evaluation signal (D1, D2) as points in time (t11, t12,
12 t21, t22), at which a coincidence event appears.

1 14. Use of the method according to one of the preceding
2 claims in a keyless locking system for motor vehicles for
3 determining the distance between a transmitting and
4 receiving station provided in the motor vehicle and a
5 further transmitting and receiving station provided in a
6 key module.